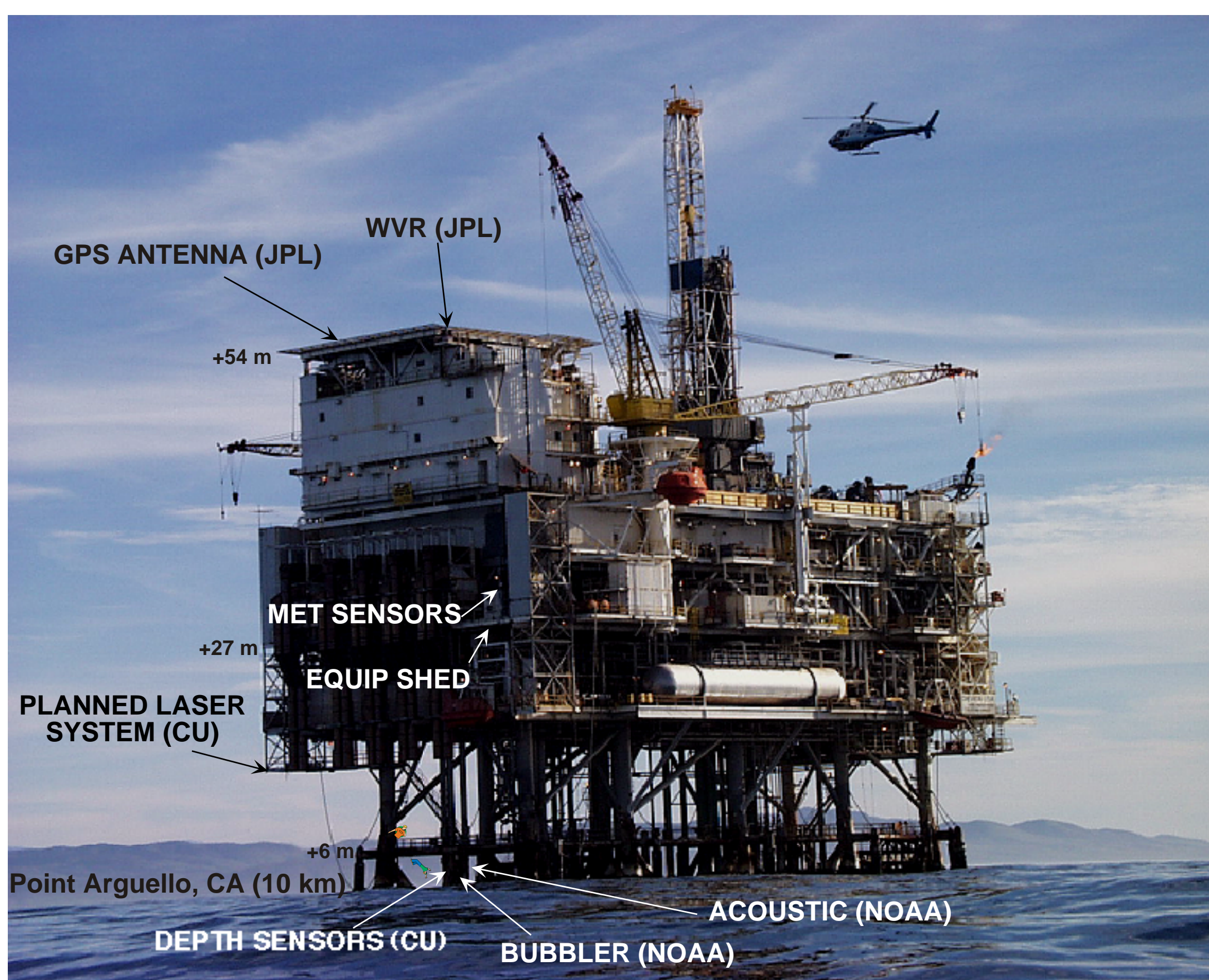# GPS Monitoring of Tide Gauges at the Harvest Platform: Geodetic Results from 1992–2000

B. Haines, S. Desai and D. Dong (*Jet Propulsion Laboratory, Calif. Inst. of Technology, Pasadena, CA, USA*)
G. Born (*University of Colorado, Boulder, CO, USA*), S. Gill (*NOAA, Natl. Ocean Service, Silver Spring, MD, USA*)

Harvest Experiment

The *Arguello Inc.* Harvest Oil Platform is located about 10 km off the coast of central California near Point Conception. Attached to the sea floor, the platform sits in about 200 m of water near the western entrance to the Santa Barbara Channel. In addition to its primary mission to drill for oil, Harvest has served since 1992 as a calibration site for the TOPEX/POSEIDON (T/P) mission. The T/P repeat ground track passes within ±1 km of the platform, and the satellite passes directly overhead every 10 days while tracing out its global pattern of sea-level measurements. The Jason-1 mission (planned summer 2001 launch) will follow the same ground track, implying that Harvest will continue to serve a vital role in validating data from precise spaceborne radar altimeter systems.

Platform GPS System

Data from the platform GPS system have been collected continuously (with a few short interruptions) since 1992, making the site one of the oldest contributing stations in the International GPS Service. The original receiver (8-channel AOA TurboRogue) served from 1992–1999. Its replacement, a 12-channel AOA Benchmark, will soon be joined by an Ashtech Z12 to provide competing measurements from the same antenna.

The antenna is a Dorne-Margolin choke ring, and is protected from the harsh marine environment by a clear radome. A custom-designed monument on the sloping roof of the heliport stairwell (at nearly the highest point of the platform superstructure) hosts the antenna mount. NOAA /NOS personnel performed repeated local surveys to measure the height (46.041 m) of the GPS marker above the tide gauge leveling points with an accuracy of 4 mm.

Platform Tide Gauges

During most of the T/P mission, three independent sea-level systems have provided measurements to support the calibration exercise. The NOAA/NOS Next Generation Water Level Measurement System (NGWLMS) consists of a self-calibrating acoustic sensor and a secondary digital "bubbler". In anticipation of Jason-1 launch, NOAA/NOS personnel are planning to replace the entire NGWLMS system with an updated version. The University of Colorado maintained submerged pressure transducers from 1992–1999. To support Jason-1, they will be deploying an experimental optical (laser) system.

Wave conditions at Harvest are typical of the open ocean. Wind waves and swell average over 2 m, but significant wave heights in excess of 7 m have been experienced during powerful winter storms:

Data Courtesy SIO/CDIP Program (Harvest Buoy)
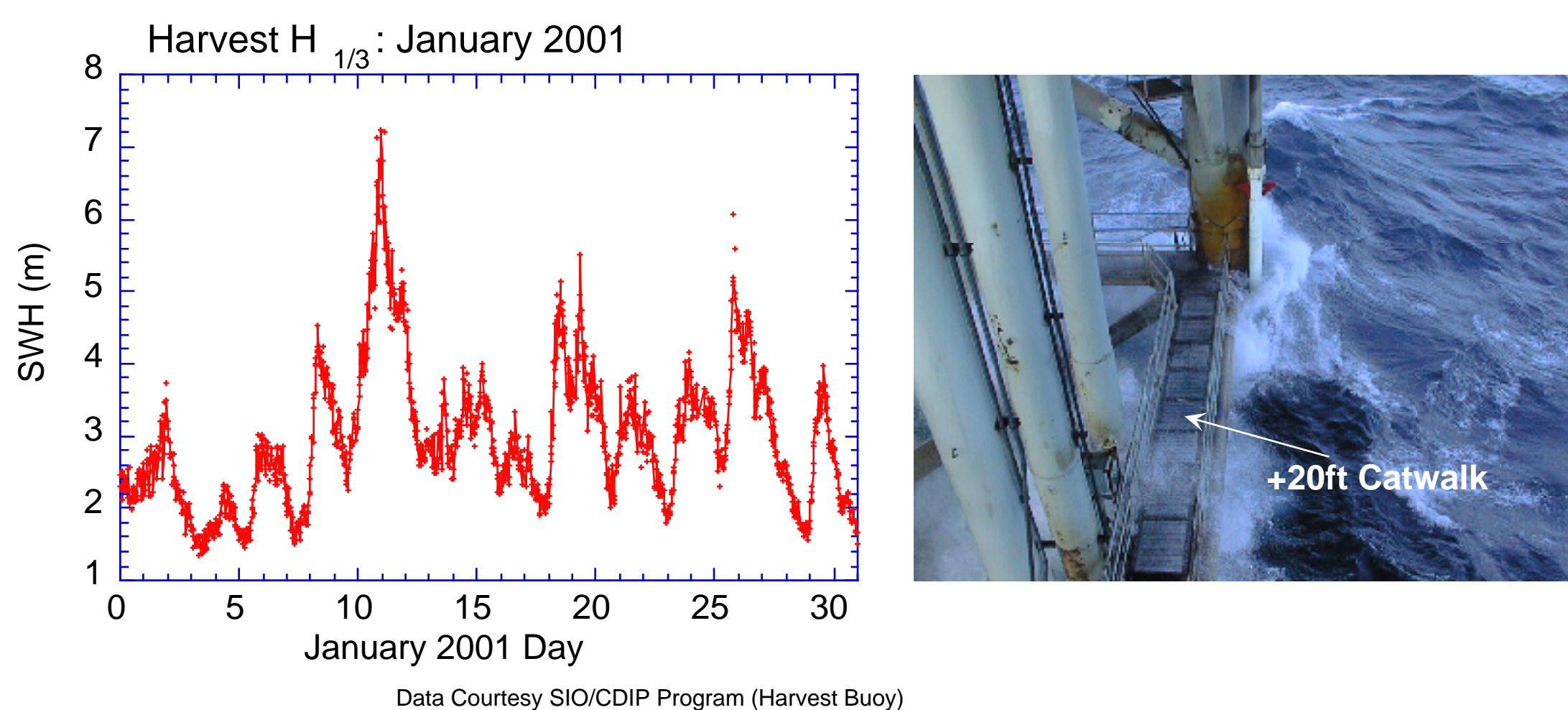
While this complicates interpretation of the tide-gauge observations, it offers that advantage that the altimeter measurement system is being monitored over a range of normal operating conditions. *Parke and Gill* [1995] have developed empirical sea-state corrections for the data from each of the Harvest tide gauges, and much has been learned about the behavior of tide gauge observations in harsh open-ocean conditions.

Vertical Platform Motion

Shown in the panel below is a time series of the platform geodetic height based on daily precise point positioning of the GPS data (ITRF97).
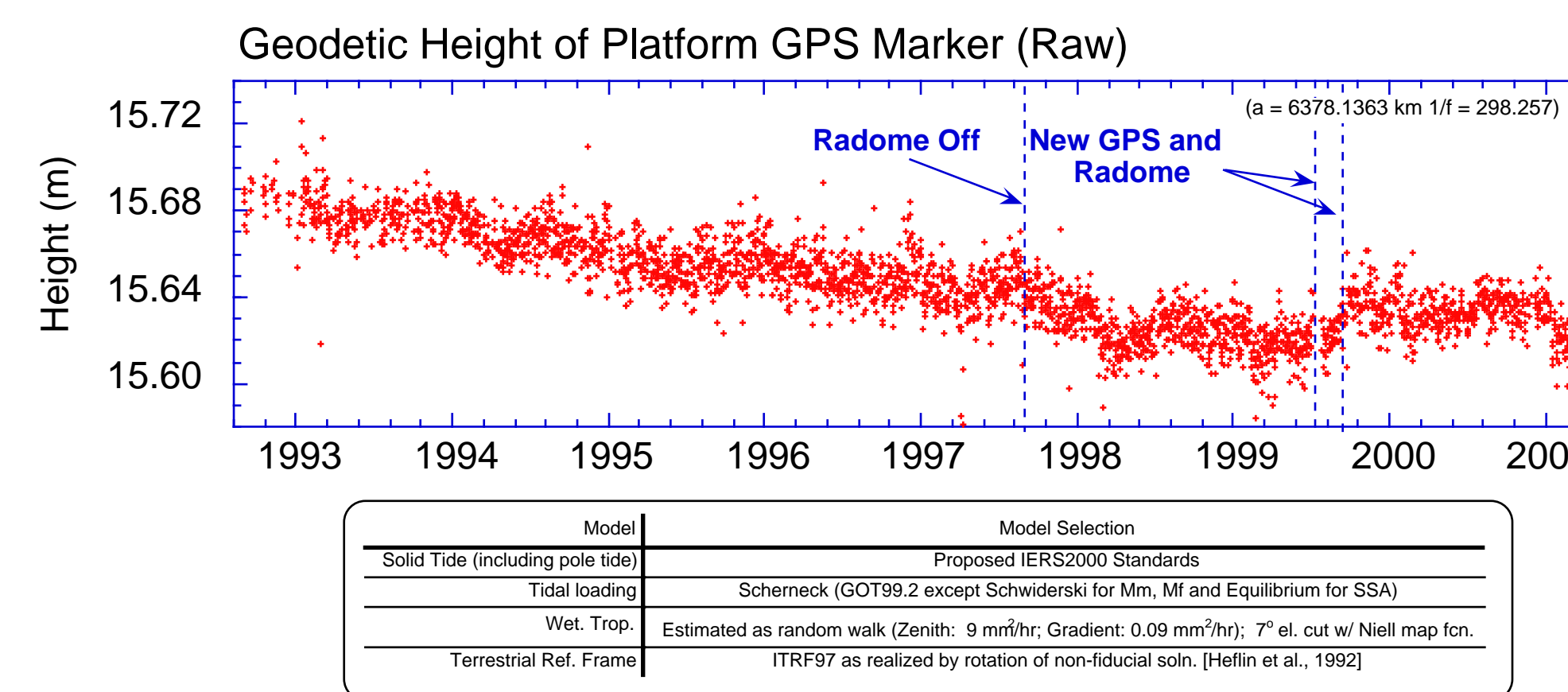

To account for spurious jumps introduced by receiver/radome changes, height offsets are estimated. The vertical velocity is also adjusted to account for a suspect 1.6 mm yr^{-1} regional subsidence as inferred from a comparison of vertical velocities from regional GPS[1] and satellite laser ranging stations with long occupation histories.[2] The conditioned time series is shown below:
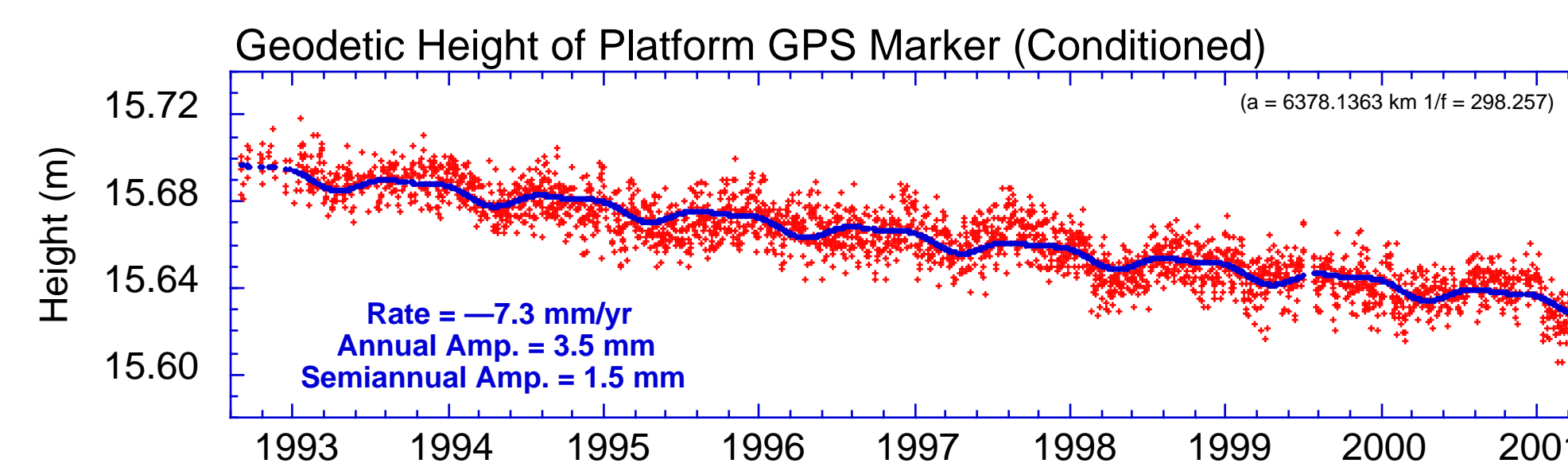
The most conspicuous feature of the plot is downward trend signifying the subsidence of the platform. This is a likely consequence of the extraction of oil from the underlying Arguello deposit. Fitted annual and semiannual variations are also shown in the plot. A frequency spectrum plot of the vertical time series also reveals energy at wavelengths centered on 1.5 yr and 3.8 yr:
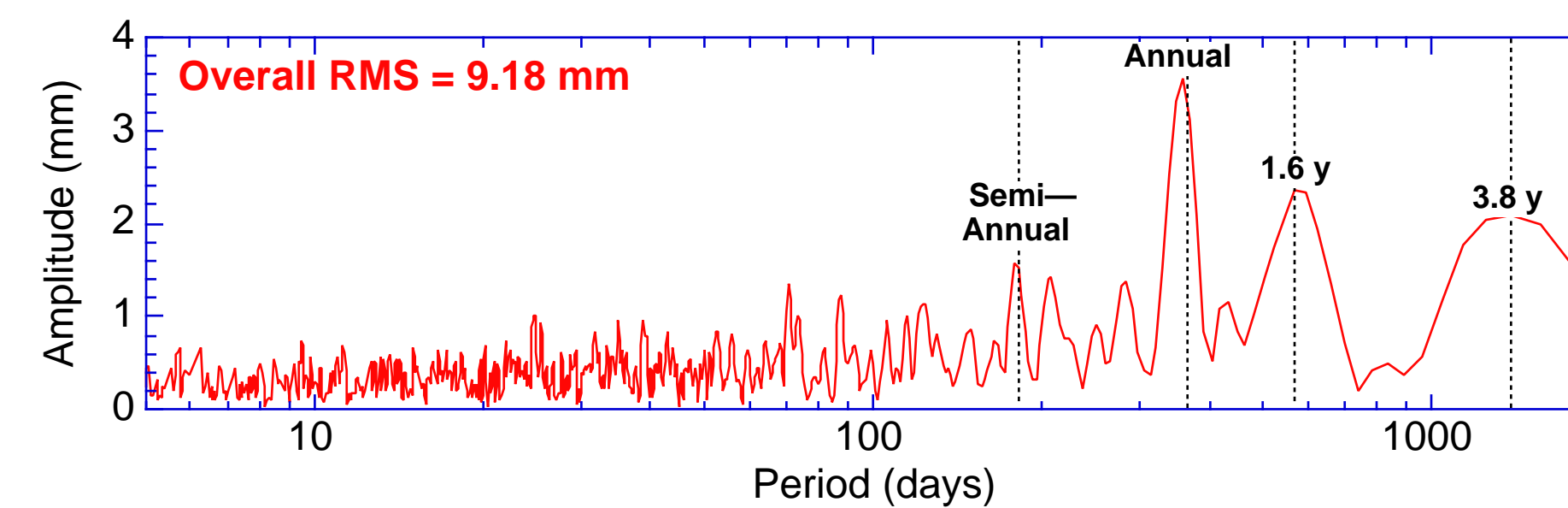
The largest signal occurs at the annual frequency. Following *Dong et al* [2001], various unmodeled crustal loading effects were investigated as potential explanations:
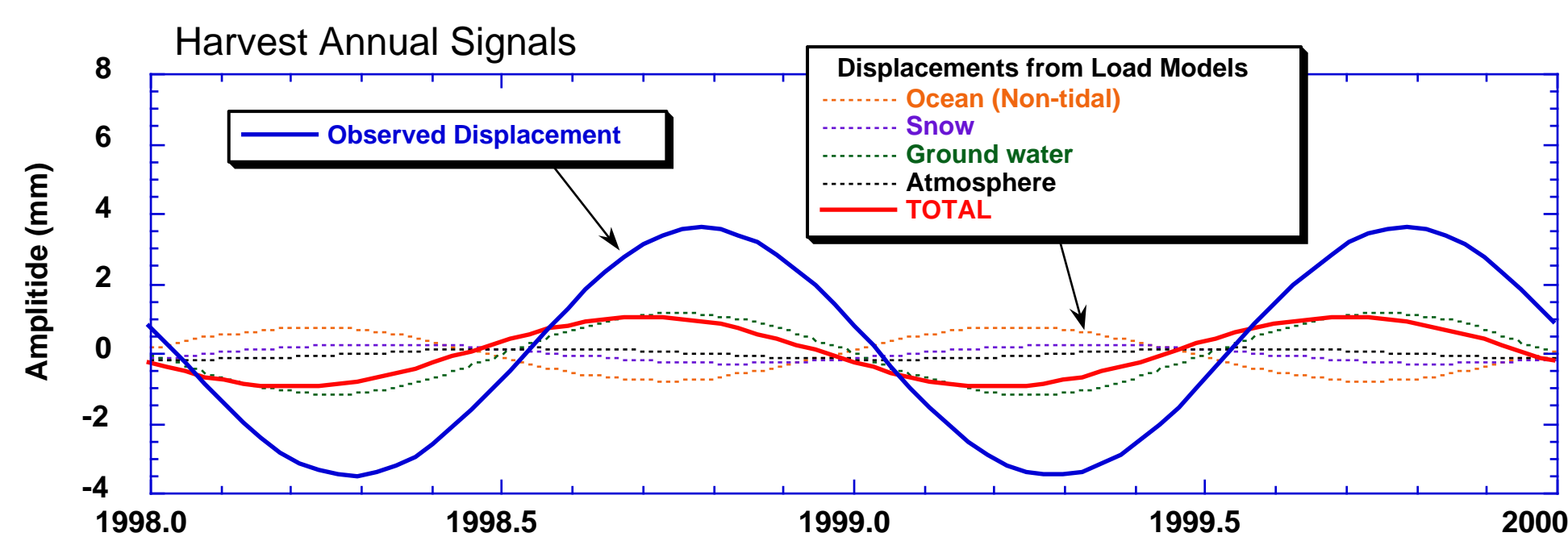

The relatively small magnitudes of the theoretical displacements do not support crustal deformation as an explanation for annual vertical motion at Harvest.[3] Also under investigation are spurious effects in the realization of the TRF, as well as thermal expansion and contraction of the platform. The observed deformation is in phase with the annual SST signal, peaking in the Fall.

Tropospheric Modeling Effects

To quantify the effect of tropospheric mismodeling on the Harvest vertical, we processed the complete time series with a significantly different strategy for tropospheric recovery. Time and frequency depictions of the residuals (w.r.t. the nominal solution) are given below:
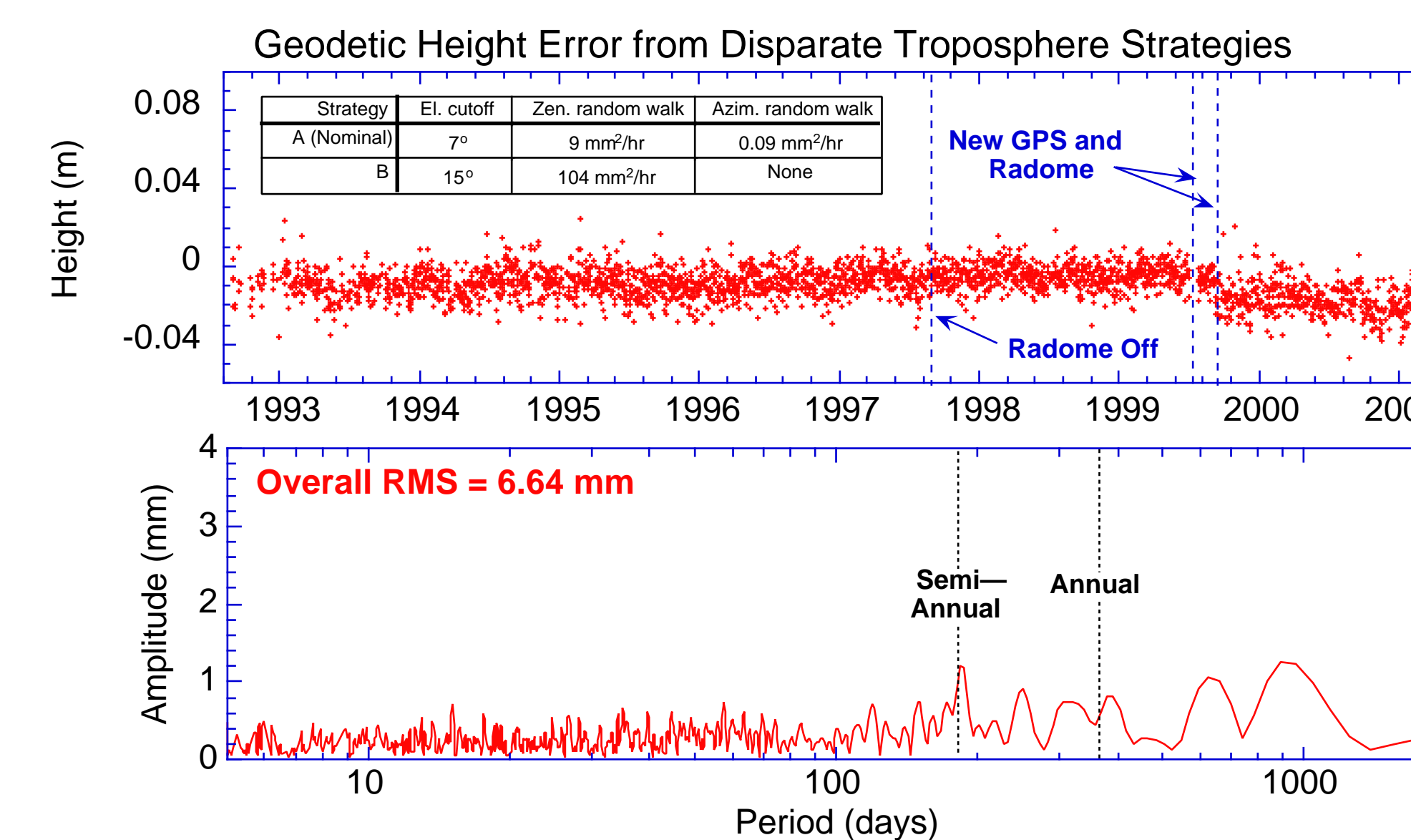
The estimate for the drift term shows slight sensitivity (~0.6 mm yr^{-1}) to the troposphere strategy. Periodic signals are spread over many frequencies.

TOPEX/POSEIDON Calibration

In the T/P calibration exercise, the platform vertical is modeled using terms for the bias, drift and annual cycle. The current SSH calibration time series (ALT– Harvest) is given below for the TOPEX altimeter:
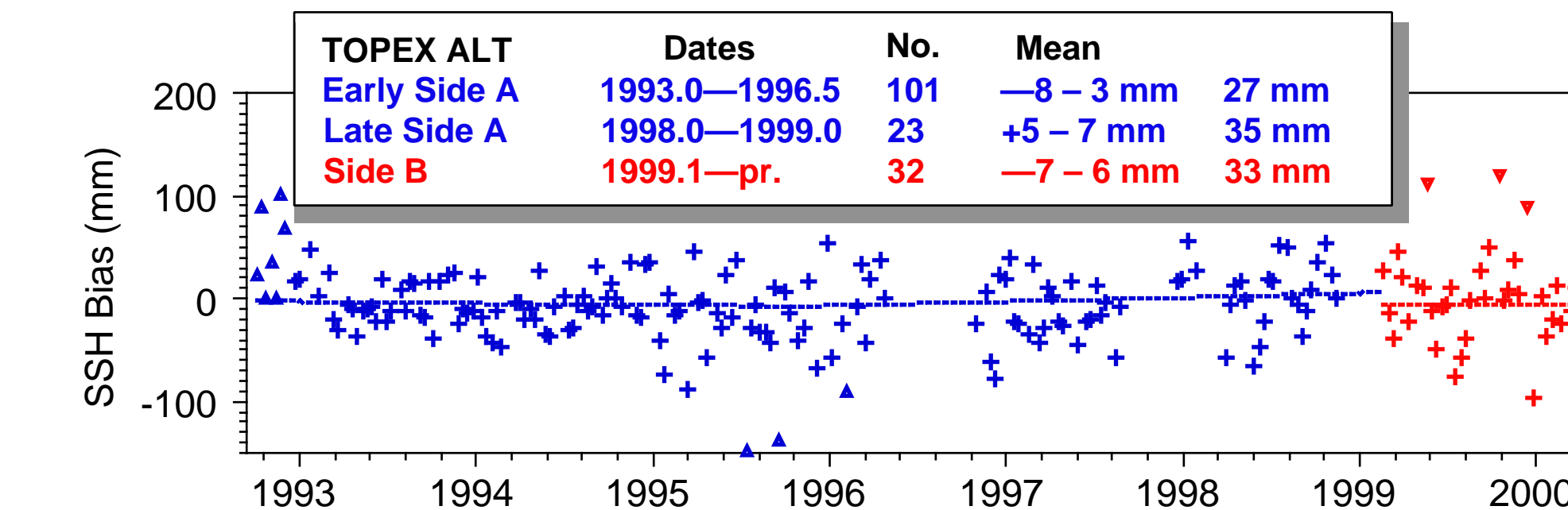
The Side B data are in excellent agreement with the Side A data collected prior to the gradual degradation in the Point Target Response (beginning mid-1996). The relative bias (Early Side A vs. Side B) computed in this fashion is not statistically distinguishable from zero. The random error estimates must be augmented by the systematic uncertainty of 1–2 cm in the absolute geocentric height and ~1 mm yr^{-1} in the subsidence rate. These figures are based principally on discrepancies in competing approaches to realizing the TRF [e.g., 1,2], and recovering the troposphere.

1 The weighted average of vertical velocities for 6 California GPS stations with long occupation histories is –1.6 ± 0.3 mm yr^{-1}. (*Heflin et al*, 2000, ITRF97/JPL results for GOLD, GOL2, JPLM, QUIN, PINY and VNDP).
2 The vertical rate for QUIN from SLR is +0.3 mm yr^{-1} (CSR96L01) vs. –1.7 mm yr^{-1} from GPS (ITRF97/JPL).
3 Tidal loading was not considered in this figure. However, the annual constituent is modeled in the GPS processing. Moreover the location of Harvest near the nodal line suggests that magnitude of the residual error is likely to be quite small.